

1    **USE OF OUTDOOR RANGES BY LAYING HENS IN DIFFERENT SIZED**  
2    **FLOCKS**

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15    **Abstract**

16    In studies assessing outdoor range use of laying hens, the number of hens  
17    seen on outdoor ranges is inversely correlated to flock size. The aim of this  
18    study was to assess individual ranging behavior on a covered (veranda)  
19    and an uncovered outdoor run (free-range) in laying hen flocks varying in  
20    size. Five to ten percent of hens (aged 9 to 15 months) within 4 small (2-  
21    2500 hens), 4 medium (5-6000), and 4 large ( $\geq 9000$ ) commercial flocks  
22    were fitted with RadioFrequencyIDentification (RFID) tags. Antennas were  
23    placed at both sides of all popholes between the house and the veranda  
24    and the veranda and the free-range. Ranging behavior was directly  
25    monitored for approximately three weeks in combination with hourly  
26    photographs of the free-range for the distribution of hens and six hour long  
27    video recordings on two parts of the free-range during two days. Between  
28    79 and 99% of the tagged hens were registered on the veranda at least  
29    once and between 47 and 90% were registered on the free-range at least  
30    once. There was no association between the percentage of hens registered  
31    outside the house (veranda or free-range) and flock size. However,  
32    individual hens in small and medium sized flocks visited the areas outside  
33    the house more frequently and spent more time there than hens from large  
34    flocks. Foraging behavior on the free-range was shown more frequently  
35    and for a longer duration by hens from small and medium sized flocks than  
36    by hens from large flocks. This difference in ranging behavior could account  
37    for the negative relationship between flock size and the number of hens  
38    seen outside at one point of time. In conclusion, our work describes  
39    individual birds` use of areas outside the house within large scale  
40    commercial egg production.

41    **Keywords: Laying hen; Flock size; Free-range; RFID**

## 42        **1. Introduction**

43    Animal friendly production systems are gaining popularity in Europe and  
44    elsewhere (Magdelaine and Mirabito, 2001). Especially in poultry, animal  
45    welfare concerns are being raised by the public regarding intensive  
46    husbandry practices, particularly in regard to high density systems with  
47    thousands of animals (Kunzmann, 2011). Perceived natural production and  
48    animal welfare are central concepts mentioned by consumers regarding  
49    quality of food (Brunsjø, 2002 in Grunert, 2005). Laying hens ranging  
50    outside fit into these perceived concepts. For instance British consumers  
51    consider free-range eggs more animal-friendly than cage eggs (Bennett  
52    and Blaney, 2003).

53        However, most laying hens are kept in large flocks and only a small  
54    percentage can be seen outside the house at any one time (e.g. Bubier and  
55    Bradshaw, 1998). Generally, flock size inversely correlates to the number  
56    of hens observed outside (Bubier and Bradshaw, 1998; Bestman and  
57    Wagenaar, 2003; Gilani et al., in press; Hegelund et al., 2005; Kijlstra et al.,  
58    2007; Whay et al., 2007), although other factors, e.g., stocking density and  
59    rearing conditions with or without access to outside areas can affect this  
60    behavior, were not controlled for and represent confounds (except in Gilani  
61    et al., in press). It is also not clear whether the same birds consistently  
62    venture onto the range, or whether different birds use the range at different  
63    times. Recent findings by Richards et al (2011) indicated that the majority  
64    of the flock ventured into the pophole at some point during the laying cycle,  
65    though they were unable to confirm if birds continued onto the range or the  
66    associated duration. Other influences on the percentage of a flock  
67    observed outside include genetics (Icken et al., 2008), weather (Gilani et  
68    al., in press; Hegelund et al., 2005) (Richards et. al., 2011), experience  
69    through exposure to an outside area during rearing (Grigor et al., 1995a;

70 but see Gilani et al, in press) or age (Bestman and Wagenaar, 2003; Icken  
71 et al., 2008), cockerel presence and ratio, cover (Bestman and Wagenaar,  
72 2003; Gilani et al., in press; Hegelund et al., 2005), light intensity in the  
73 house and pop hole availability (Gilani et al., in press), diversity of  
74 structures (Zeltner and Hirt, 2008), vegetation (Nicol et al., 2003), and the  
75 presence of keel bone fractures (Richards et al., 2012). Different reasons  
76 for the unexpected low range usage may include: fear (of predation,  
77 novelty) (Grigor et al., 1995b), presence of unfamiliar birds (Grigor et al.,  
78 1995c), missing feeding times in the hen house (Bubier and Bradshaw,  
79 1998), or unattractive habitat (e.g. due to destruction by the hens) (Bubier  
80 and Bradshaw, 1998). Higher stress can also be associated with a higher  
81 use of the outdoor area (Mahboub et al., 2004).

82 Range size is typically proportional to flock size but often most hens are  
83 seen in a small area immediately surrounding the house (Hirt et al., 2000;  
84 Zeltner and Hirt, 2003; Elbe et al., 2005). The concentration of grazing may  
85 lead to a problematic accumulation of nitrogen due to faeces (Aarnink et al.,  
86 2006) and destruction of grass cover. Given the lack of accurate  
87 information regarding individual hens` usage of the range and the  
88 implications for flock management, we sought to provide this information  
89 using a radio frequency identification (RFID) system that could accurately  
90 track the passage of hens` entry and exit onto the range. The aim of this  
91 study was to assess individual ranging behavior within system containing a  
92 covered (veranda) and an uncovered outdoor run (free-range) in laying hen  
93 flocks varying in size. Verandas provide many potential welfare benefits of  
94 outdoor runs. Verandas also provide their own benefits including: space for  
95 extensive locomotion, foraging, dust-bathing, lower density in the house  
96 and the veranda, and reduced exposure to UV light while protecting birds  
97 from adverse weather, predation, and infection from wild birds. In pursuit of

98    this aim we monitored the frequency and duration of visits to the outdoor  
99    areas, the behavior of birds on the range, as well as the distance from the  
100    house. We also assessed these variables to determine the effect of flock  
101    size (independent of stocking density).

## 102        **2. Materials and Methods**

### 103        **2.1. Flocks**

104        Characteristics of the investigated flocks are shown in Table 1. The  
105        particular flock sizes chosen were based on Swiss legislation which limits  
106        number of laying hens that a farmer is allowed to keep to a maximum of  
107        18,000 (Verordnung 916.344, 26.11.03),  
108        [http://www.admin.ch/opc/de/classified-](http://www.admin.ch/opc/de/classified-compilation/20030950/index.html#a2)  
109        [compilation/20030950/index.html#a2](http://www.admin.ch/opc/de/classified-compilation/20030950/index.html#a2), accessed 5-31-13). Thus,  
110        commercial flocks numbering from 2,000 to 18,000 hens were chosen for  
111        investigation. As most laying hens in Switzerland are white hybrids and no  
112        large flocks with brown hybrids were available, all flocks (n = 8) in the small  
113        (2,000 to 2,460 hens) and large (9,000 to 18,000 hens) categories were  
114        white. Half (two) of the medium sized flocks consisted of brown hybrids. All  
115        hens were between 9 and 14 months of age. During rearing after the 42<sup>nd</sup>  
116        day of age flocks had access to a veranda but not to a free-range. They  
117        were given access to a free-range from the 24<sup>th</sup> week of age onwards. The  
118        flocks were housed in single and multitier systems with access to separate  
119        outdoor ranges (Fig 1). All houses had an adjacent covered outdoor run  
120        (hereafter called 'veranda<sup>2</sup>') with a concrete floor with litter. Verandas were  
121        positioned on one long side of the house except on farm 2. At the opposite  
122        long side of the veranda, hens had access to an open outdoor range  
123        consisting of grassland and, on some farms, trees, shrubs, or artificial  
124        shelters (e.g. elevated nets) (hereafter called 'free-range<sup>2</sup>'). For all flocks,  
125        an area approximately ten meters adjacent to the veranda was without  
126        vegetation but covered with gravel stones of various sizes except on Farm  
127        3 where shredded bark was provided..

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<sup>2</sup> Terms used by EFSA ([www.efsa.europa.eu](http://www.efsa.europa.eu))

128 Flocks were considered to be statistically independent because they lived  
129 in different buildings with different ranges although three were located on  
130 one farm and two belonged to the same farm in two instances. Flock sizes  
131 were balanced in regard to the seasons and years; stocking density was  
132 constant across all flocks (according to Swiss legislation). Spring was  
133 defined as mid-March until the end of June and fall as the period between  
134 the end of August and the end of November. Due to equipment limitations,  
135 the use of the veranda of one flock (farm 8) was measured after  
136 assessment of the range during January; use of the veranda of the flocks  
137 (farm 6) was not assessed. Three flocks (farm 4, 6) had been reared on  
138 the same farm; the others had been bought from rearing farms.

139

## 140 **2.2 Housing**

141 With the exception of farm 2, all houses were equipped with aviaries  
142 that consisted of several tiers where feed, water, and perches were  
143 provided. Space on the litter and at the feeders, number of drinkers, and  
144 perch length per bird were maintained in compliance of Swiss legislation.  
145 The outdoor areas veranda and free-range as well as the total space of  
146 pop-holes and the management of using these areas conformed to Swiss  
147 regulations for subsidies and were controlled by officials regularly. Faeces  
148 were removed by mechanically driven belts approximately once a week.  
149 Farm 2 had a floor housing system with perches, raised areas with litter,  
150 and a manure pit. In all houses, group laying nests were attached to the  
151 walls of the hen houses or on a tier of the aviary rack. Access points  
152 between the house and the veranda and the veranda and the free-range  
153 (termed popholes) varied in size and numbers with flock size. Access to the  
154 veranda began between 5:30 and 10:00 h and concluded between 16 to  
155 18:00 h depending on individual farm protocol. Access to the free-range via

156 the popholes was provided from between 8 and 12:00 h to 16 to 18:00 h  
157 also depending on individual farm protocol. No housing parameters or  
158 management procedures were altered during data acquisition to obtain an  
159 accurate representation of bird movements within the flock.

160

### 161 **2.3 RFID equipment**

162 Antennas of the *Gantner Pigeon System* (<http://www.benzing.cc/>, accessed  
163 on Feb. 21, 2013) were placed on either side of each pophole linking the  
164 house/veranda and veranda/free-range at least three weeks before data  
165 were collected to allow birds to acclimate to the presence of the antennas.  
166 The width of the popholes ranged from 1.2 to 4.6 m. Depending to the size  
167 of the pophole, up to 12 antennas, six on each side of the pophole, were  
168 put side-by-side to cover the entire width (Gebhardt-Henrich et al., 2011).  
169 The RFID system operated by registering and recording the time and date  
170 that individual tags (ø 4.0 / 34.0 mm Hitag S 2,048 bits, 125 kHz, attached  
171 to leg bands worn by the birds and described in detail below) came within  
172 15 cm vertical distance of an antenna. The inclusion of antennas on either  
173 side of the pophole represents an added level of assurance as transition  
174 between two areas required registration of two events – both entrance into  
175 the pophole in one area (e.g. inside the house) followed by exit from the  
176 pophole into a second area (e.g. to the veranda). Collected data, including  
177 the unique tag identification number, timestamp (with a precision of 0.1 s),  
178 and the antenna number, were written to a connected computer. The  
179 system allowed for multiple tags (and the associated hen) to be registered  
180 by the same antenna at the same time. The direction of movement was  
181 referred from the sequence of antennas. More details of the RFID system  
182 and its reliability are provided in Gebhardt-Henrich et al. (2011).

183



## 184        **2.4 Procedures**

185            Hens were acclimated to the presence of the equipment (e.g.,  
186    antennas and cables) at least three weeks before data collection. At night  
187    when hens were perching in the dark house, RFID tags were attached to  
188    10% of the hens of the first three flocks (summer 2008 - to spring 2009)  
189    and later to 5% of the flock via a stratified selection process to insure  
190    representative covering of all locations in the hen house (i.e., aviary, litter,  
191    slats, nestbox). A blue head lamp was used and all hens remained at their  
192    position during tagging. Each building was divided into different sections  
193    and the same number of tags were used in each section. Tags, previously  
194    placed inside a wing band, were mounted to one leg of the hen with an  
195    adjustable RFID leg band, both commercially available (IDs, Roxan,  
196    Scotland). At depopulation, most tags were recovered (Table 1). Tags that  
197    were not recovered were excluded from analyses. Ten flocks were  
198    monitored at least 21 days during which access to the outdoor ranges was  
199    provided, though in some cases inclement weather caused the producer to  
200    deny free-range access and reduced the number of days assessments  
201    could be made of free-range usage. Two flocks were monitored for 18  
202    (farm 3, 6000 hens) and 19 days (farm 2).

203            On two days without rain during the recording period, the entire free-  
204    range was photographed every hour between 10:00 and 16:00 h. Weather  
205    conditions (e.g. sunshine, temperatures, wind exposure etc.) could not be  
206    standardized and varied across farm. Resulting images were used to count  
207    the number of hens in the different parts of the free-range relative to  
208    vegetation, shelters, and distance from the house. In one flock (Farm 4)  
209    crowding prevented reliable counting and on this farm no photographs were  
210    taken. During the same period that photographs were taken, video  
211    recordings were made of two areas next to the veranda (one area covered

212 with pebbles and a second with grass) to provide a behavioral assessment  
213 of each flock within these areas. Recordings were coded with Observer 5.0  
214 software (Noldus Information Technology, Wageningen, The Netherlands)  
215 using behaviors defined in an established ethogram (Table 2). At the top of  
216 each hour, a focus hen was chosen which was closest to the center of the  
217 screen and observed for 5 min. If the hen left the screen before the 5 min  
218 observations could be completed, another hen was chosen for observation  
219 from the center of the screen and observed as long as she was visible or  
220 until the 5 min were over. These observations were repeated to obtain 5  
221 min of observation time for each area at every hour that access to the free-  
222 range was provided.

223

## 224 **2.5 Analyses**

225 The reliability of registration by the RFID equipment largely depended on  
226 the velocity of the hens as they passed through the popholes with 1.5 m/s  
227 representing a threshold above which greater velocities reduced reliability  
228 (Gebhardt-Henrich et al., 2011). When calculating durations of stay, two  
229 missed registrations of a tag as it passed over an antenna would distort the  
230 measured duration considerably. Therefore, only durations on days when  
231 the individual hen had 100% matching registrations, i.e. each passage to  
232 the free-range required a passage back to the veranda etc., were included  
233 in the final data set. When discrepancies in the dataset were identified,  
234 e.g. daily time records for individual hens where time spent on the veranda  
235 and/or free-range did not equal the time outside the house, these records  
236 were deleted. Durations of stays on the veranda or free-range shorter than  
237 0.5 min. were excluded. Median duration on the veranda and the free-range  
238 were calculated for each hen, day, and each farm separately.

239 Data were checked for normality with the Kolmogorov-Smirnov test and  
 240 the daily duration on the veranda and the free-range were logarithmically  
 241 transformed as was duration of sitting, standing, and the ratio of foraging to  
 242 walking.  
 243 Data were analyzed using SAS® 9.1.3 and 9.2. Full models including all  
 244 interactions were computed first. Non-significant interactions ( $p > 0.2$ ) were  
 245 pooled. Individual Spearman`s correlations were calculated between daily  
 246 duration on the free-range with number of days on the free-range and  
 247 between daily duration on the free-range with the time of day they went out  
 248 then averaged per farm. To test for the presence of bimodality, the  
 249 coefficient of bimodality was calculated as  $(\text{skewness}^2 + 1) / \text{kurtosis}$  where  
 250 a value greater than 0.555 indicates bimodality (Freeman and Dale, 2013),  
 251 (calculated by Proc MODECLUS in SAS®  
 252 <http://support.sas.com/documentation/onlinedoc/stat/121/modeclus.pdf>,  
 253 accessed on 6-3-2013). For the analyses, 0.555 was deducted from each  
 254 calculated coefficient and determined whether equal to 0 by a sign test in  
 255 Proc UNIVARIATE (SAS®). The test statistic  $M$  was calculated as  $M =$   
 256 (number of values greater than 0 - number of values smaller than 0). To  
 257 account for the bimodal distribution of use of the outdoor ranges the  
 258 frequency of ranging was analysed as a bimodal variable (at least or less  
 259 than 2/3 of the days) with Proc GENMOD (SAS®) using farm as a subject  
 260 factor. A generalized linear model with maximum likelihood estimation was  
 261 used and the p-values based on their chi-square distributions. The  
 262 estimated parameters of the [generalized linear\\_model](#) GEE are given in the  
 263 text. Further details about the specific analyses are given with the  
 264 results. The experiment was approved by the Office of Agriculture of the  
 265 Canton Bern for all Swiss cantons (19/07).

### 3. Results

#### 3.1. Registration on veranda and free-range

During the investigation  $90.4\% \pm 2.2$  (mean  $\pm$  standard error) of the marked laying hens per flock were registered on the veranda and  $70.5\% \pm 3.4$  were registered on the free-range at least once (Table 1). There was no association of flock size on the percentage of tagged hens on the veranda ( $r^2 = 0.14$ ,  $N = 10$ , NS) or on the free-range ( $r^2 = 0.08$ ,  $N = 12$ , NS). However, individual hens used the veranda and the free-range differently and many of them did not enter the veranda or the free-range every day (Table 3). Using the hens registered in the outdoor areas at least once as a subset of the overall dataset, the number of days when the veranda or free-range was used had bimodal distributions (Fig. 2 a, b) and confirmed by the coefficients of bimodality being larger than 0.555 (number of days on the veranda:  $M = 5$ ,  $P = 0.002$ ,  $N = 10$ , number of days on the free-range:  $M = 6$ ,  $P = 0.0005$ ,  $N = 12$ ).

Individuals as well as farms differed in the daily duration on the free-range (mixed model, farm:  $F_{9,23000} = 697.26$ ,  $P < 0.0001$ , individual nested in farm:  $F_{1735,23000} = 9.77$ ,  $P < 0.0001$ ). When attendance of the free-range is categorized into spending  $\frac{1}{4}$ ,  $\frac{1}{2}$ ,  $\frac{3}{4}$ , and more than  $\frac{3}{4}$  of the days there, hens going to the free-range more often also spent more time there (repeated analysis with farm as the subject factor,  $F_{3,32} = 500.69$ ,  $P < 0.0001$ ). This means that hens which spent a greater daily amount of time in the outdoor areas were more likely to spend more days in those areas, as well. The proportion of hens in the categories using the free-range at least or less than  $\frac{2}{3}$  of the days was influenced by flock size: Flock size was negatively associated with the percent of days spent on the free-range ( $\chi^2_2 = 7.85$ ,  $P = 0.02$ , small flocks = 0, medium flocks = -1.23, large flocks = -1.68, modeling the category 'spending more than  $\frac{2}{3}$  of all days on the

294 free-range') and the duration ( $\chi^2_2 = 8.15$ ,  $P = 0.02$ , small = 0, medium = -  
 295 295.3, large = -319.3, for the variable total time on the free-range[min.]).  
 296 Similarly, the number of hens in a flock was negatively correlated with the  
 297 percentage of days that were spent on the veranda ( $r_s = -0.66$ ,  $P = 0.04$ ,  $N$   
 298 = 10). The duration spent on the veranda was significantly different among  
 299 flock sizes ( $F_{2,5} = 13.13$ ,  $P = 0.01$ , least square means, log transformed:  
 300 small =  $4.22 \pm 0.077$  (4 flocks), medium =  $3.80 \pm 0.077$  (4 flocks), large =  
 301  $3.65 \pm 0.09$  (2 flocks)) while the contrasts between large vs. medium and  
 302 small flocks as well as small vs. medium and large flocks were significant  
 303 ( $F_{1,5} = 11.56$ ,  $P = 0.02$ ;  $F_{1,5} = 25.65$ ,  $P = 0.004$ ). The sooner after the  
 304 opening of the popholes the hens went out on the free-range compared  
 305 with other hens on the same farm, the greater the total duration on the free-  
 306 range was ( $r_s = -0.55 \pm 0.03$ ,  $P < 0.0001$ ,  $N = 12$  flocks).

307

### 308 **3.2. Areas of the free-range**

309 The percentage of hens seen on the area with gravel adjacent to the  
 310 veranda vs. the percentage of hens on the grass varied among flocks but  
 311 was not correlated with flock sizes ( $r_s = -0.28$ ,  $P = 0.40$ ,  $N = 11$ ). The mean  
 312 percentage of hens on the free-range that were underneath artificial  
 313 structures was 6.8 % (minimum, maximum: 0.2, 69%); underneath  
 314 vegetation like bushes or trees 22.4% (minimum, maximum: 3.9, 57.7%);  
 315 and on open grass 41.8% (minimum, maximum: 31.8 and 60.7%).

316

### 317 **3.3. Behavior on the free-range**

318 Hens spent more time moving (walking and foraging) on grass than on  
 319 gravel ( $F_{1,9} = 13.01$ ,  $P = 0.006$ ) though was unrelated to flock size ( $F_{2,9} =$   
 320  $1.64$ ,  $P = 0.25$ ). However, the ratio of foraging to walking differed both for  
 321 the location (i.e., grass or gravel) and flock size (location:  $F_{1,9} = 49.51$ ,  $P <$

322 0.0001, size:  $F_{2,9} = 12.43$ ,  $P = 0.003$ , interaction between location and flock  
323 size:  $F_{2,9} = 2.4$ ,  $P = 0.15$ , Fig. 3) with hens generally foraging more on grass  
324 than on gravel. Large flocks displayed less foraging behavior than medium  
325 and small flocks (contrast:  $F_{1,9} = 11.63$ ,  $P = 0.008$ ), a relationship  
326 maintained when brown hybrids are excluded (contrast:  $F_{1,7} = 10.03$ ,  $P =$   
327  $0.016$ ). Hens stood longer on gravel than on grass ( $F_{1,9} = 12.95$ ,  $P = 0.006$ )  
328 and their sitting duration varied with flock size ( $F_{2,7} = 5.05$ ,  $P = 0.044$ ).

329

#### 330        **4. Discussion**

331        To the authors' knowledge, this is the first study monitoring continuous  
332        ranging behavior of individual hens in large scale commercial flocks where  
333        no aspect of their housing (e.g. size and number of popholes) was altered.  
334        Previous related work included small experimental groups of 50 birds  
335        (Mahboub et al., 2004) and a flock of 12,000 that was divided into groups of  
336        1,500 birds (Richards et al., 2011). In this latter study however, registration  
337        in the pophole rather than time on range was recorded, thus the  
338        methodology did not allow quantification of actual time on range or if the  
339        hen actually exited the house. Hens in studies by Icken et al. (2008, 2011)  
340        had a veranda though no free-range. In this regard, this is the first study to  
341        test the influence of flock size on the number of hens on a veranda and  
342        free-range and the duration of their stay in those areas.

343

##### 344        **4.1 Flock size and numbers of ranging hens**

345        Although there was no significant influence of flock size on the percentage  
346        of hens that were registered at least once on the veranda and/or the free-  
347        range during three weeks, flock size was associated with the behavior of  
348        the hens in the outdoor areas. Unexpectedly, many hens that were  
349        registered on the veranda or the free-range during the investigation did not  
350        go there every day. The average number of hens seen outside at any one  
351        time is similar to that seen in other studies (Fig. 4, Supplementary data)  
352        which showed an inverse relationship between flock size and hens outside.  
353        Taken together, these results suggest that while the percentage of the flock  
354        on the range at any point in time varies and is relatively low, the percentage  
355        of the flock that actually uses the range at some point is much higher, a  
356        finding which raises several important issues. Firstly, the ability to range  
357        might be important to a large percentage of the flock and not just a subset

358 of hens. Given the varied systems that are currently being developed for  
359 laying hen production as replacements for battery cages, our results  
360 suggest consideration should be given to ranging ability given the  
361 widespread usage. Particularly given that hens in semi-natural conditions  
362 spend most of their time foraging (Savory et al., 1978), our results suggest  
363 that this is a behavior which is maintained in current genetic stock despite  
364 intense breeding. Secondly, assuming that ranging is a critical behavior  
365 which some hens have a strong motivation to perform, research is needed  
366 to assess the variable use of the range with varying flock size, changes in  
367 individual bird behavior, and consequences to animal welfare.

368         Our methodology also indicated a bimodal distribution of hen: those  
369 using the free-range every day for a long time and those using the free-  
370 range sporadically for short periods of time. It is unclear whether these  
371 differences present unique personality types, e.g. as shown in great tits  
372 between fast and slow explorers and individuals dispersing and philopatric  
373 birds (Dingemanse et al., 2003), or some other mechanism. The  
374 percentage of days when hens used the free-range was associated with  
375 flock size so environmental effects on this trait are likely although a genetic  
376 component might also be present (Drent et al., 2003; Van Oers et al.,  
377 2004). Substantial individual variation in the length of stay on the veranda  
378 was also found by Icken et al. (2008) and in the frequency of pophole use  
379 by Richards et al. (2011). In the latter study 80% of the hens frequently  
380 used the popholes but length of stay on free-range was not measured.

381         Long and frequent stays on the free-range are sometimes taken as  
382 indicators for good welfare (Swiss Animal Protection, pers. comm.) though  
383 scientific evidence for this is lacking. Since we did not assess welfare-  
384 related parameters we cannot interpret our results in this respect, though  
385 our methodology and results offer an interesting means to interpret



assumptions regarding welfare and range use. Knierim (2006) states that access to free-range offers opportunities both to increase and decrease welfare. On the one hand access to a free-range provides enrichment for the hens improving welfare, while predation, diseases, or an imbalanced diet might decrease welfare. Other studies have shown that use of an outdoor range reduces feather pecking which is thought to be redirected foraging behavior (Green et al., 2000; Bestman and Wagenaar, 2003; Nicol et al., 2003; Mahboub et al., 2004; Whay et al., 2007) and thus improves welfare. Given our methodology and results, we should interpret these findings at the individual level to ensure theoretical benefits are actually realized throughout the flock rather than an unknown and likely variable subset of animals.

398

#### 399 **4.2 Flock size and behavior of hens on free-range**

Foraging (moving with head held low) was observed more on grass than on gravel and more in small and medium sized flocks than in large flocks, for reasons that are not clear. Hens in semi-natural conditions spend most of their time awake foraging (Savory et al., 1978). Those hens were released on an island and they were not fed by people. Hens in larger flocks might have foraged more inside the house where they were not observed. The interior of hen houses of larger flocks might have been more attractive than the houses of smaller flocks due to environmental (e.g. improved temperature regulation with more birds, more absolute space), social (e.g., greater feelings of security), or nutritional (e.g., increased number of feeders) factors, though appropriately designed studies would need to test these possibilities.

It is important to note that flock sizes were not manipulated so that causality cannot be concluded. Care was taken to balance flock sizes with

414 environmental conditions (seasons and years). However, farms differed in  
415 many aspects and this likely plays a role in the large variation in range use  
416 and behavior. Weather conditions like cloud cover which is known to  
417 influence ranging behavior could not be standardized. Some flocks were  
418 located on the same farm and thus were not entirely independent. Due to  
419 the small sample size of twelve flocks, parameters like hybrid,  
420 management, size of popholes, and structure of the free-range could not be  
421 analyzed. Instead of standardization, a realistic variation in these  
422 parameters was selected to provide representative results that could be  
423 applied to commercial conditions. In this sense the flock with the fewest  
424 hens registered on the free-range (47%) and the flock with one of the  
425 highest registrations (90%) belonged to flocks of 6,000 hens. The free-  
426 range that was only visited by 47% of the tagged hens consisted of grass  
427 only. Outdoor areas without structures and shelters are known to attract  
428 fewer hens (Bestman and Wagenaar, 2003; Zeltner and Hirt, 2003; Zeltner  
429 and Hirt, 2004; Hegelund et al., 2005; Zeltner and Hirt, 2008). Likewise, the  
430 distribution of hens with regard to the distance to the house which was not  
431 associated with flock size might have been influenced by the structure and  
432 vegetation of the free-range (Zeltner and Hirt, 2003). Brown hybrids range  
433 more than white hybrids (Mahboub et al., 2004) and this was reflected in  
434 this study where the duration outside was highest in the medium sized  
435 flocks that contained two brown flocks. These influences, namely hybrid  
436 and range characteristics, seemed more important than flock size to predict  
437 how many hens were entering the outdoor areas. However, these results  
438 cannot be readily extrapolated to small groups of hens or much larger  
439 flocks that are common outside Switzerland.

440         In even small flocks an uneven distribution of hens crowding near  
441 the house was detected similar to the findings of Elbe et al (2005). They

442 measured a high concentration of the amount of nitrogen in the soil of up to  
443 2086 kg N / ha close to the house. Similar figures are probably true for our  
444 flocks and could be a problem for the environment.

445

#### 446 **4.4 Conclusion**

447 Although a majority of hens visited the veranda and at least half of the  
448 tagged birds accessed the free-range, relatively few hens used those areas  
449 extensively every day. Usage of the outdoor ranges had a bimodal  
450 distribution where a subpopulation of hens appeared to use the range with  
451 different patterns, i.e. many days at a long duration or infrequently of short  
452 duration. The proportion of hens using the outdoor ranges frequently was  
453 greater in small and medium sized flocks. The reason of the association  
454 between time on the free-range and flock size and the implications for the  
455 welfare of the hens in small and large flocks between 2,000 and 18,000  
456 hens remain unclear and should be studied further.

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472

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609

## List of Figures

**Fig. 1.** Drawing of a laying hen house with the different outdoor ranges veranda and free-range. Antennas were placed on both sides of the popholes between the house and the veranda and between the veranda and free-range. A part of the free-range closest to the veranda was without vegetation, mostly consisting of gravel.

**Fig. 2.** Bimodal distributions of the percentage of days that hens entered the veranda (a) and the free-range (b). Data of all farms are pooled. The height of the bars denotes the percentage of hens in the flock that falls into the following categories: using the veranda (a) or free-range (b) up to 10 % of the monitored days (bar at the most left), between 10 and 20% of the days (next bar to the right) etc.

**Fig. 3.** Boxplots (showing the median (50th percentile) line inside box, the third quartile (75th percentile) upper edge of box, the first quartile (25th percentile) lower edge of box, and the minimum and the maximum (endpoints of lower and upper whiskers) of the ration between foraging and walking movements for hens on the gravel and vegetation portions of the free-range in differently sized flocks. Significant differences are marked with different letters.

**Fig. 4.** Relationship between flock size and number of birds seen outside at one instance. The references and actual numbers are shown in Appendix 1. The outside areas are classified as veranda when they were covered or free-range when they were uncovered. The data of the present study are included but distinguished by separate symbols.

Table 1

**Table 1.** Attributes of the investigated flocks and the number of tags which were recovered during depopulation (% recovered), how many tagged hens were registered at the antennas inside of the house (% house), at the antennas at the outer side of the popholes between house and veranda or the antennas at the inner side of the popholes between veranda and free-range (% veranda), and at the antennas on the free-range (% free-range). LSL are white and LB are brown hens. The number and the width [m] of the popholes between house and veranda and veranda and free-range are given. On farm 5 the size of the popholes between veranda and free-range were variable and ranged between 1.2 (1 pophole) and 4.6 m (4 popholes).

# hens	Hybrid <sup>1</sup>	Season	Farm	House veranda	- Veranda free-range	- % recovered	% house	% veranda	% free-range
2,000	HN White	Spring 09	1	4 (1.15)	3 (1.5)	84	99	98	90
2,000	LSL	Fall 09	2	2 (3)	1 (5)	68	87	82	72
2,000	HN White	Spring 10	3	5 (1.2)	2 (1.2)	72	97	90	63
2,460	HN White	Fall 08	1	5 (1.2)	3 (1.5)	77	97	90	66
5,000	LB	Fall 08	4	8 (1.2)	8 (1.5)	72	97	96	85
5,600	HN Brown	Spring 10	1	13 (1.3)	11 (1.5)	88	100	99	90
6,000	HN White	Fall 09	3	9 (1.2)	3 (4.6)	91	98	96	47
6,000	LSL	Spring 09	5	8 (1.2)	5 (var.)	82	98	91	78
9,000	LSL	Fall 10	6	-	13 (3)	68.2	-	-	70
9,000	LSL	Fall 10	6	-	13 (3)	82	-	-	70
12,000	LSL	Spring 08	7	15 (1.5)	10 (2)	22	83	79	56
18,000	LSL	Fall 09	8	21 (1.2)	15 (2.25)	85	88	83	59

<sup>1</sup> Hybrids: LSL = Lohmann Selected Leghorn, LB= Lohmann Brown ([www.ltz.de](http://www.ltz.de)) HN White = H&N Nick Chick, HN Brown = H&N Brown Nick ([www.hn-int.com](http://www.hn-int.com))



**Table 2.** Ethogram of behaviors scored from collected video recordings. Each flock was videotaped at two locations on the free-range on two non-rainy days between 10 and 16 hrs. One location was close to the veranda without vegetation and the other location was on the grass further away from the veranda.

Behavior	Definition
Sit	Stationary, legs are not visible
Stand	Stationary, at least one leg is visible and stretched, no pecking
Walk	Locomoting with head above the body
Forage	Locomoting with head below the body, or standing and pecking

**Table 3.** Summary statistics of the ranging behavior in the twelve flocks. Summary statistics were only computed when a particular hen had no mismatching records for a day (see text). Means with standard errors are provided for the number of hens as indicated. This number includes only those hens in the flock that were registered on the veranda and the free-range and whose tags were recovered at depopulation. Durations are given in min. % veranda is the percentage of days that hens visited the veranda and % free-range is the percentage of days that hens visited the free-range.

# hens	Veranda	Free-range	% veranda	% free-range	N hens
2,000	98.27 ± 7.05	31.00 ± 4.12	85.15 ± 1.80	54.13 ± 2.73	196
2,000	67.09 ± 11.25	14.67 ± 2.52	86.49 ± 2.73	54.67 ± 4.84	76
2,000	107.42 ± 11.17	54.88 ± 9.90	91.38 ± 2.48	78.24 ± 3.99	96
2,460	61.13 ± 5.57	18.18 ± 3.07	70.76 ± 2.34	53.54 ± 3.06	222
5,000	127.90 ± 8.08	102.13 ± 55.31	90.76 ± 1.02	85.17 ± 0.91	347
5,600	113.25 ± 10.59	36.89 ± 3.75	70.22 ± 1.60	57.42 ± 1.54	291
6,000	77.00 ± 9.95	45.45 ± 4.90	73.97 ± 1.96	70.62 ± 2.79	276
6,000	91.59 ± 5.13	52.19 ± 4.28	80.71 ± 1.84	68.35 ± 2.42	269
9,000	-	36.24 ± 4.49	-	39.92 ± 1.94	313
9,000	-	73.74 ± 8.49	-	53.43 ± 2.19	324
12,000	60.42 ± 5.05	9.77 ± 5.25	77.54 ± 2.89	52.24 ± 4.26	99
18,000	59.76 ± 3.24	37.68 ± 2.82	26.73 ± 1.30	52.81 ± 1.61	560

Fig. 1

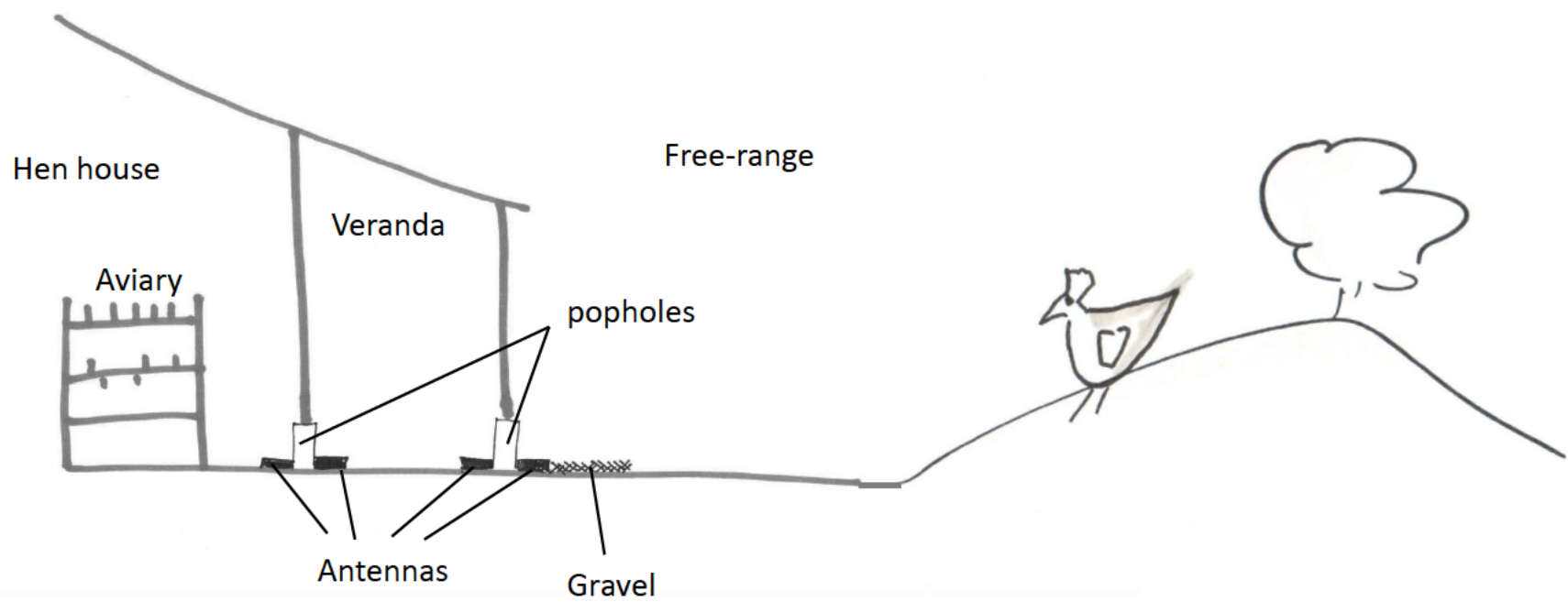


Fig. 2 a)

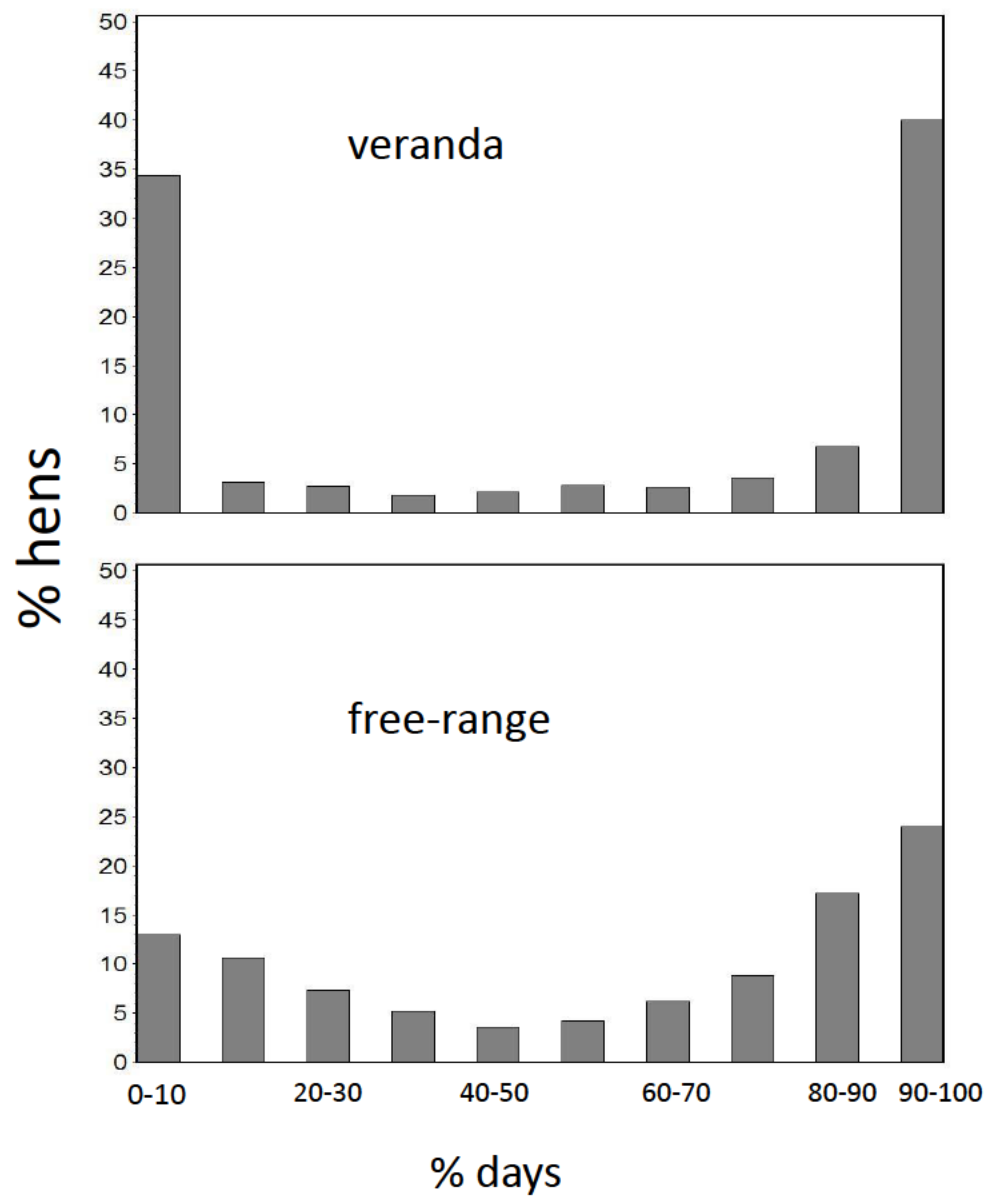




Fig. 3

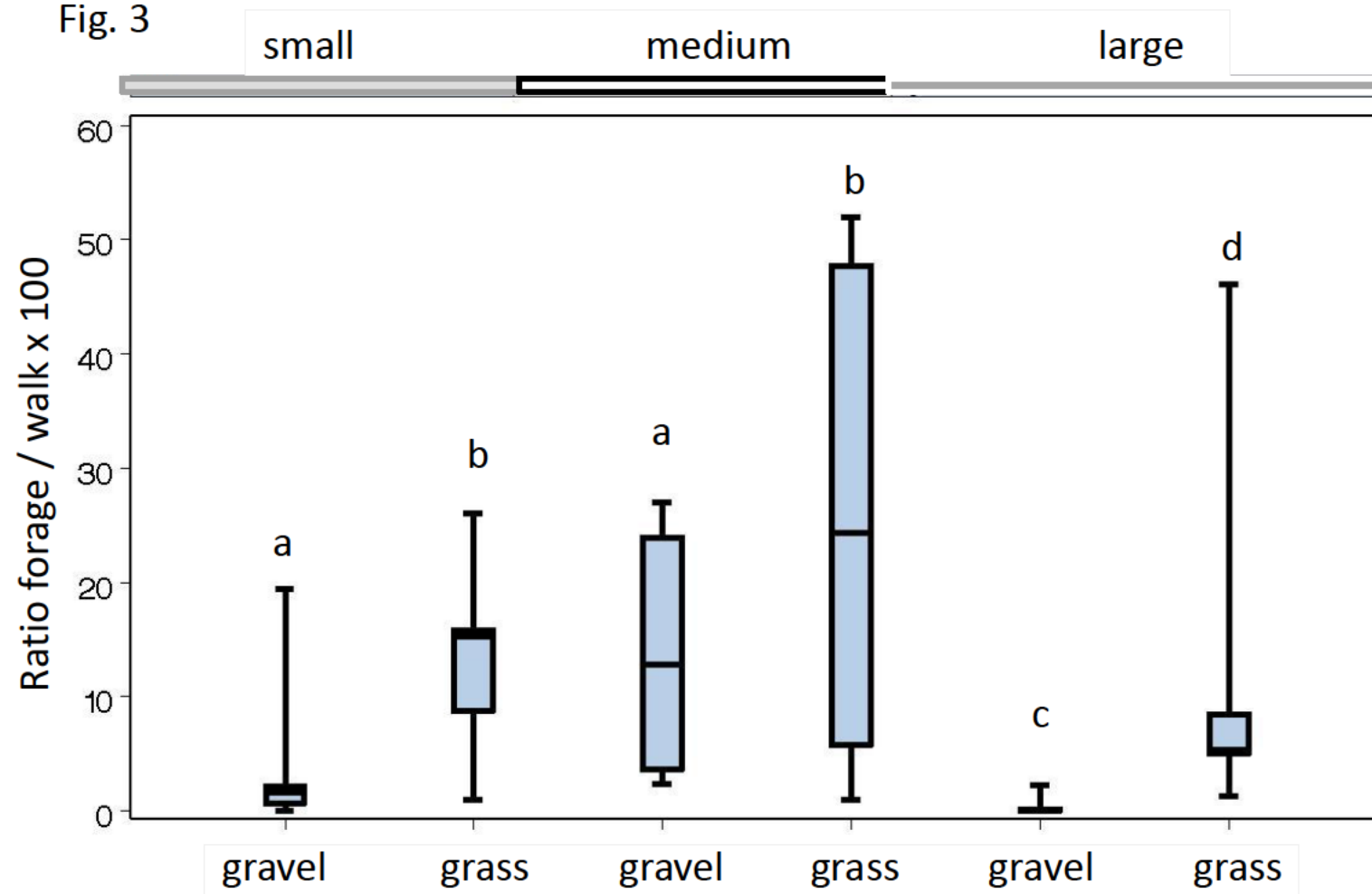


Figure  
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